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Characterization of Pliocene and Miocene Formations in the Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO2

Project Summary

February, 2009

1. **Project Background and Motivation**
2. **Geologic Overview of Offshore Wilmington Graben**
3. **Project Objectives and Technical Approach**
4. **Efforts to Date**

Project Partners:

Terralog Technologies USA, Inc (Prime Contractor)

City of Los Angeles, Department of Public Works

Port of Long Beach, Department of Planning

Cal State Long Beach

Legg Geophysics

Don Clarke Geology

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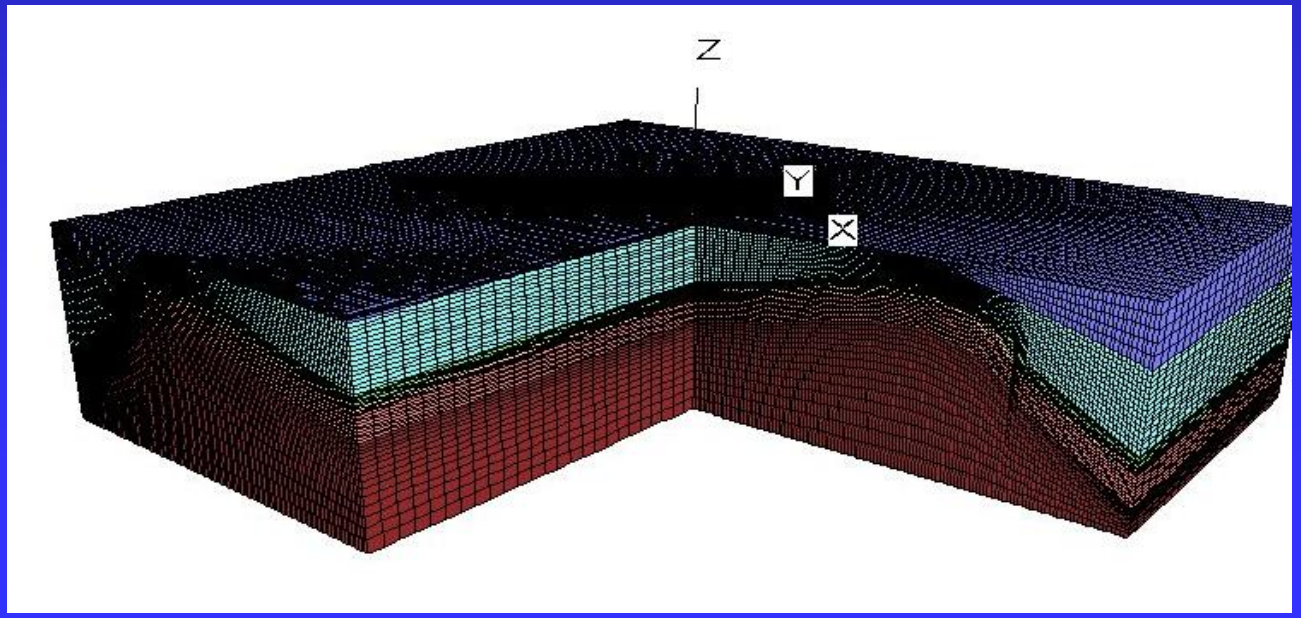
Terralog Technologies Inc.

Advanced Geomechanics from the wellbore to reservoir scale

- *Compaction and Subsidence Analysis*
- *Well Damage Analysis and Design*
- *Caprock Integrity Studies*
- *Geothermal Reservoir Studies*
- *Gas Storage Mechanics*
- *Cuttings and Production Waste Injection*
- *Salt Cavern Mechanics*
- *CO2 Sequestration*



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The Los Angeles Basin presents a very unique and special combination of great need and great opportunity for large scale geologic storage of CO2.

In part due to its significant population, and in part due to its historical and geologic setting as one of the most prolific oil and gas producing basins in the United States, the region is home to more than a dozen major power plants and oil refineries which produce more than 5 million metric tons of fossil fuel related CO2 emissions each year.

Both the City of Los Angeles and the Port of Long Beach have significant interest and efforts underway to reduce greenhouse gas emissions, while still supporting the business of energy development and Port commerce.

These efforts include the City of Long Beach *Green Port Policy* to reduce emissions, and the City of Los Angeles *GreenLA Climate Action Plan*.

The City of Los Angeles, supported by Terralog, has already obtained a Class V well construction and injection permit (and CEQA approval) to drill and core a new well in the North Wilmington Graben area, as part of its ongoing Terminal Island Renewable Energy and Carbon Sequestration Project.

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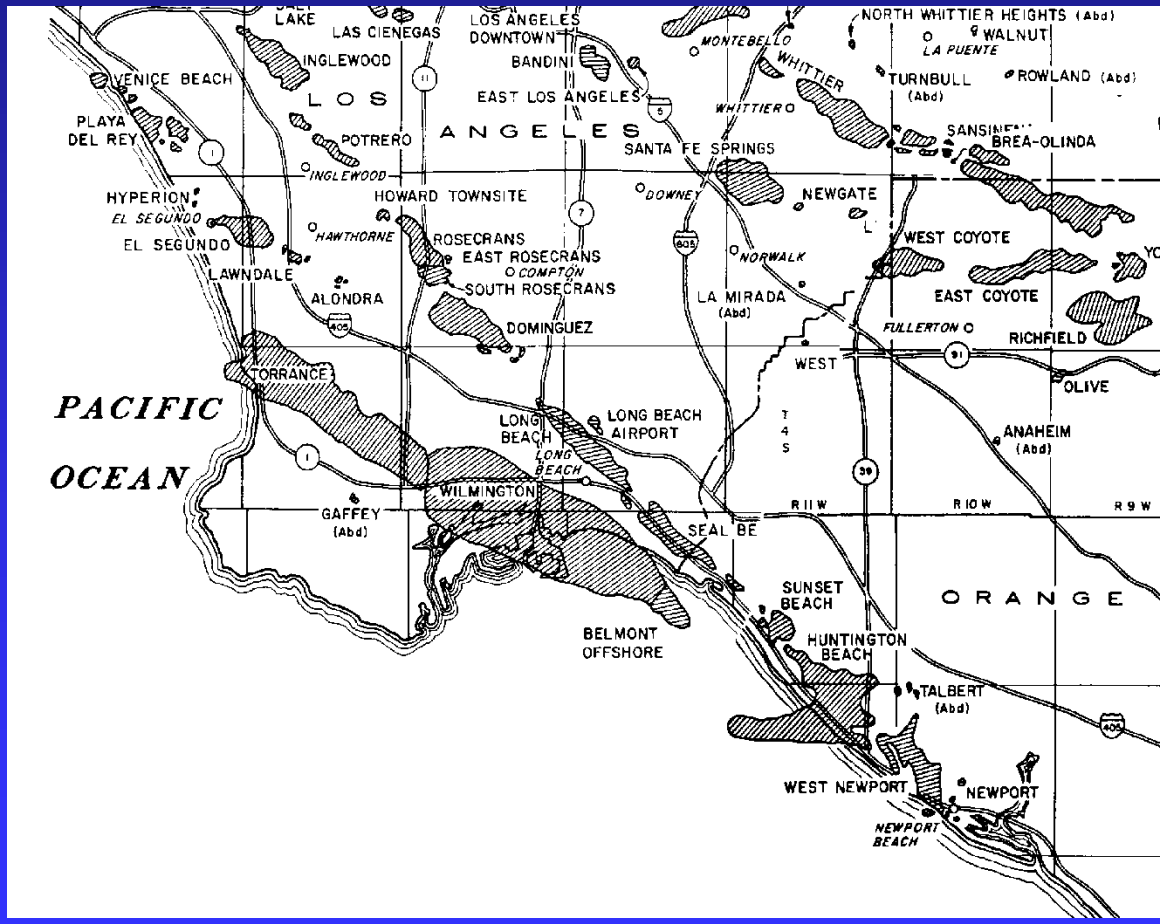
Pliocene and Miocene sediments in the Los Angeles Basin (massive interbedded sand and shale sequences) are known to provide excellent and secure traps for oil and gas.

The area contains several billion-barrel oil and gas fields, including the giant Wilmington Field in Long Beach (more than two billion barrels produced to date).

These formations have been used by Southern California Gas Company for very large scale underground storage of natural gas at half a dozen locations throughout the Los Angeles basin for more than fifty years, demonstrating both the storage potential and security of these formations for CO2 sequestration if properly characterized and selected. In a seismically active area !



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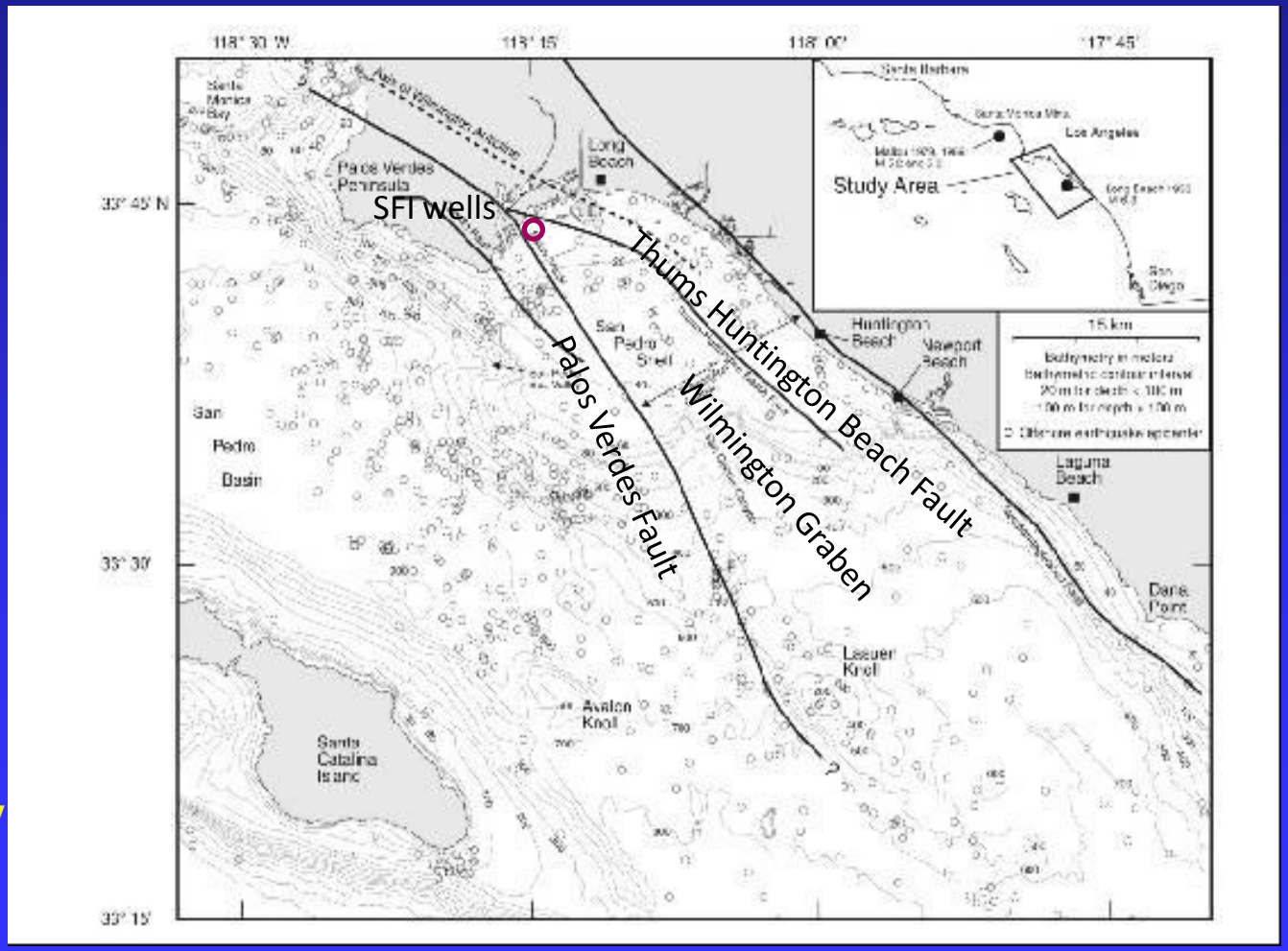
Given the current population density (and complex land ownership), it would be impractical to site a large scale CO2 storage project onshore beneath the City.

More than 3000 feet thickness of these same Pliocene and Miocene formations are present, however, in the large Wilmington Graben directly offshore the Los Angeles and Long Beach Harbor area, at appropriate depth for CO2 sequestration (about 3000 to 7000 ft).

This zone is easily accessible yet geologically isolated from the nearby Wilmington Oilfield and onshore area, reducing communication risk and public risk.



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Terralog Technologies USA, in a unique partnership with the City of Los Angeles, Department of Public Works, and the Port of Long Beach, Department of Planning, is pursuing a comprehensive research program to better characterize Pliocene and Miocene sediments in the Wilmington Graben for high volume CO2 storage. The effort will include:

1) **Improved evaluation and interpretation of existing 2D and 3D seismic data;**

2) **Acquisition and interpretation of several additional 2D seismic lines;**

3) **Detailed log evaluation of existing exploration wells in the area;**

4) **Drilling and coring two new evaluation wells into the Graben (one from City of Los Angeles Property and one from Port of Long Beach property); and,**

5) **Development of 3D geologic models, geomechanical models, and CO2 injection and migration models for the region.**

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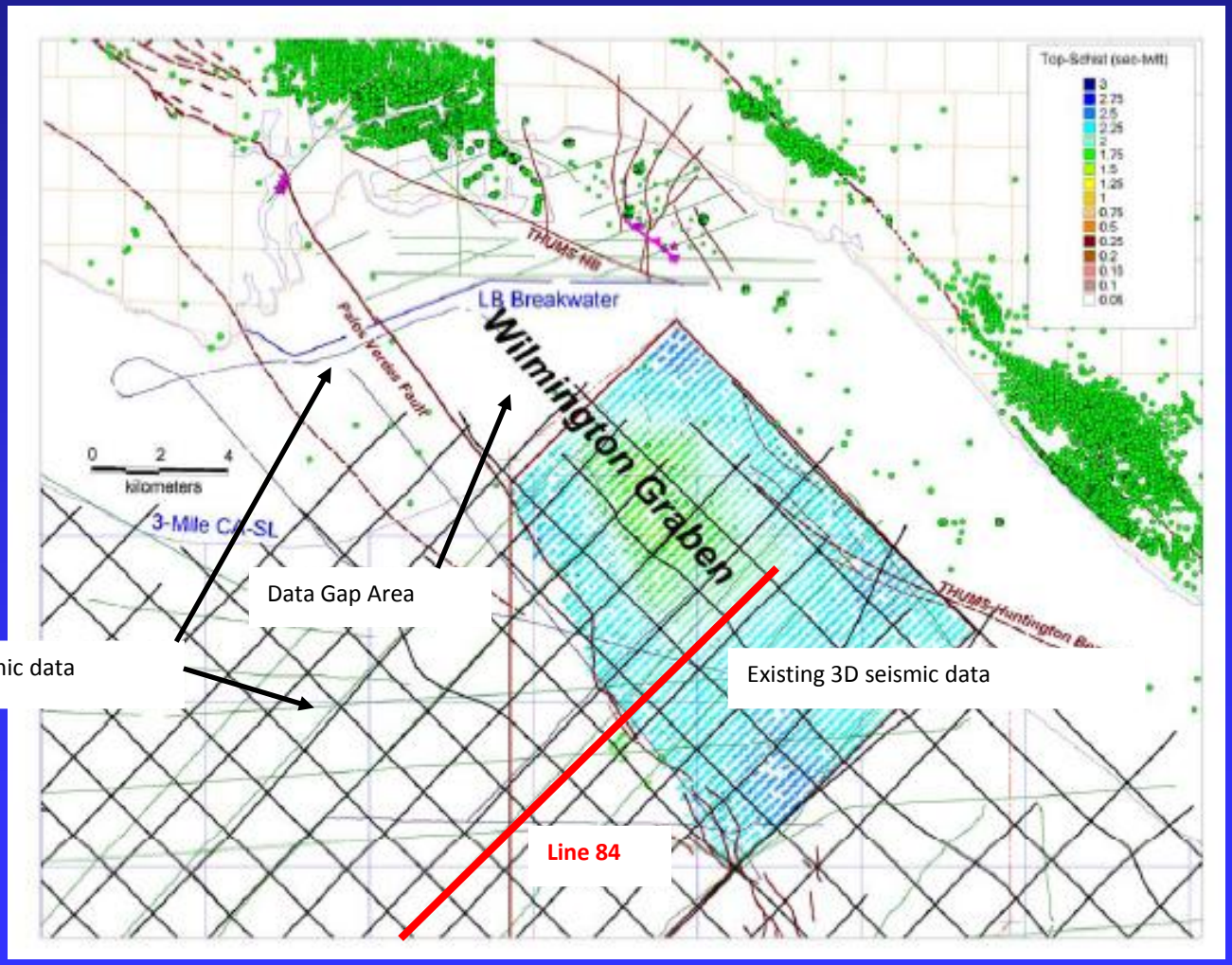

Wells in State Waters Under Review

Apinumber	Operator	Lease	Well_no	Field	Status_cod	Latitude	Longitude	Td	Sec	Twn	Rge
5907885	Chevron U.S.A. Inc.		10R-29	ORANGE COUNTY	006 plugged and abandoned dry hole	33.68716	-118.114189	3238	34	5S	12W
23700493	Exxon Mobil Corp		H 10 R-7	LOS ANGELES	006 plugged and abandoned dry hole	33.67754	-118.165218	6643	6	6S	12W
23700507	Chevron U.S.A. Inc.		10R-18	LOS ANGELES	006 plugged and abandoned dry hole	33.68891	-118.224312	5958	34	5S	13W
23719051	Mobil Oil Corp.		SP-3	LOS ANGELES	006 plugged and abandoned dry hole	33.67015	-118.202569	572	11	6S	13W
23720208	Conoco Inc.		SP S-4	LOS ANGELES	006 plugged and abandoned dry hole	33.69454	-118.18442	4775	36	5S	13W
23720211	Conoco Inc.		SP S-6	LOS ANGELES	006 plugged and abandoned dry hole	33.70187	-118.156197	5025	29	5S	12W
25920074	Chevron U.S.A. Inc.		10R-34	ORANGE COUNTY	006 plugged and abandoned dry hole	33.68089	-118.154942	6976	5	6S	12W
23719063	Westates Petroleum	Core Hole	3	LOS ANGELES	006 plugged and abandoned dry hole	33.7076	-118.235971	7133	28	5S	13W
23705997	Chevron U.S.A. Inc.	S-P La Harbor	2	LOS ANGELES	006 plugged and abandoned dry hole	33.72407	-118.242225	9936	21	5S	13W
23705998	Chevron U.S.A. Inc.	S-P La Harbor	301	LOS ANGELES	006 plugged and abandoned dry hole	33.73211	-118.26281	10569	21	5S	13W
25900374	Mobil Oil Corp.	State 3119	3	ORANGE COUNTY	006 plugged and abandoned dry hole	33.68513	-118.10696	6490	18	6S	11W
25900361	Mobil Oil Corp.		SP-11	ORANGE COUNTY	006 plugged and abandoned dry hole	33.68704	-118.136915	8423	33	5S	12W

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Wells in Federal Waters Under Review

API	Lease	Well No	Operator	TD	Form at TD	Lat	Long	Logs	Last Activity	Old Age Pen	Permit	Compl	Cores	Deviation
East of Beta														
4312200100000	OCS P-0302	1	GULF OIL CORP	6660	000UNKWN	33.5512	-118.0601	N	12/1/1998		6/20/1977	7/17/1977	N	V
4312200240000	OCS-P-0302	2	SOHIO PETROLEUM CO	7100	109BSMN	33.5724	-118.0516	Y	9/30/2002	PRECAMB	4/7/1979	5/6/1979	Y	V
4312200110000	OCS-P-0298	1	SHELL OIL CO	7200	553SCST	33.5995	-118.0345	Y	12/1/1998	U. JURASSIC	1/13/1977	2/20/1977	Y	V
North of Beta														
4312200080000	OCS-P-0293	1	SHELL OIL CO	6805	109BSMN	33.6611	-118.1405	Y	9/30/2002	PRECAMB	12/5/1976	1/21/1977	Y	V
Northwest of Beta														
4312200190000	OCS-P-0296	12	CHEVRON U S A INC	10973	000UNKWN	33.6192	-118.1603	N	12/1/1998		10/30/1977	2/5/1978	N	
4312200190100	OCS-P-0296	13	CHEVRON U S A INC	6525		33.6192	-118.1603	N	12/1/1998		1/26/1978	3/18/1978	N	
Northeast of Edith														
4312200180000	OCS-P-0296	8	CHEVRON U S A INC	6076	000UNKWN	33.6018	-118.1322	N	12/1/1998		7/2/1977	8/23/1977	N	
4312200180100	OCS P-0296	9	CHEVRON U S A INC	8400		33.6018	-118.1322	N	12/1/1998		8/11/1977	9/18/1978	N	
4312200180200	OCS P-0296	10	CHEVRON U S A INC	5726		33.6018	-118.1322	N	12/1/1998		9/10/1977	9/27/1977	N	
4312200180300	OCS-0296	11	CHEVRON U S A INC	5700		33.6018	-118.1322	N	12/1/1998		10/8/1977	1/1/1977	N	
North of Ellen														
4312200060000	OCS-P-0296	2	CHEVRON U S A INC	6000	000UNKWN	33.5908	-118.1289	N	12/1/1998		10/20/1976	1/7/1977	N	V
4312200060100	OCS-P-0296	3	CHEVRON U S A INC	5193		33.5908	-118.1289	N	12/1/1998		1/7/1977	1/29/1977	N	
4312200060200	OCS-P-0296	4	CHEVRON U S A INC	5336		33.5908	-118.1289	N	12/1/1998		1/22/1977	2/8/1977	N	
Ellen Adjacent														
4312200130000	OCS-P-0300	1	SHELL OIL CO	4850	000UNKWN	33.577	-118.1225	N	12/1/1998		3/31/1977	5/7/1977	N	V
4312200130100	OCS-P-0300	2	SHELL OIL CO	4988		33.577	-118.1225	N	12/1/1998		5/1/1977	5/16/1977	N	
Eureka Adjacent														
4312200020000	OCS-P-0301	1	SHELL OIL CO	8317	000UNKWN	33.5658	-118.1193	N	12/1/1998		6/22/1976	10/6/1976	N	V
4312200160000	OCS P-0301	6	SHELL OIL CO	5244	000UNKWN	33.5698	-118.1114	N	12/1/1998		5/30/1977	7/1/1977	N	V

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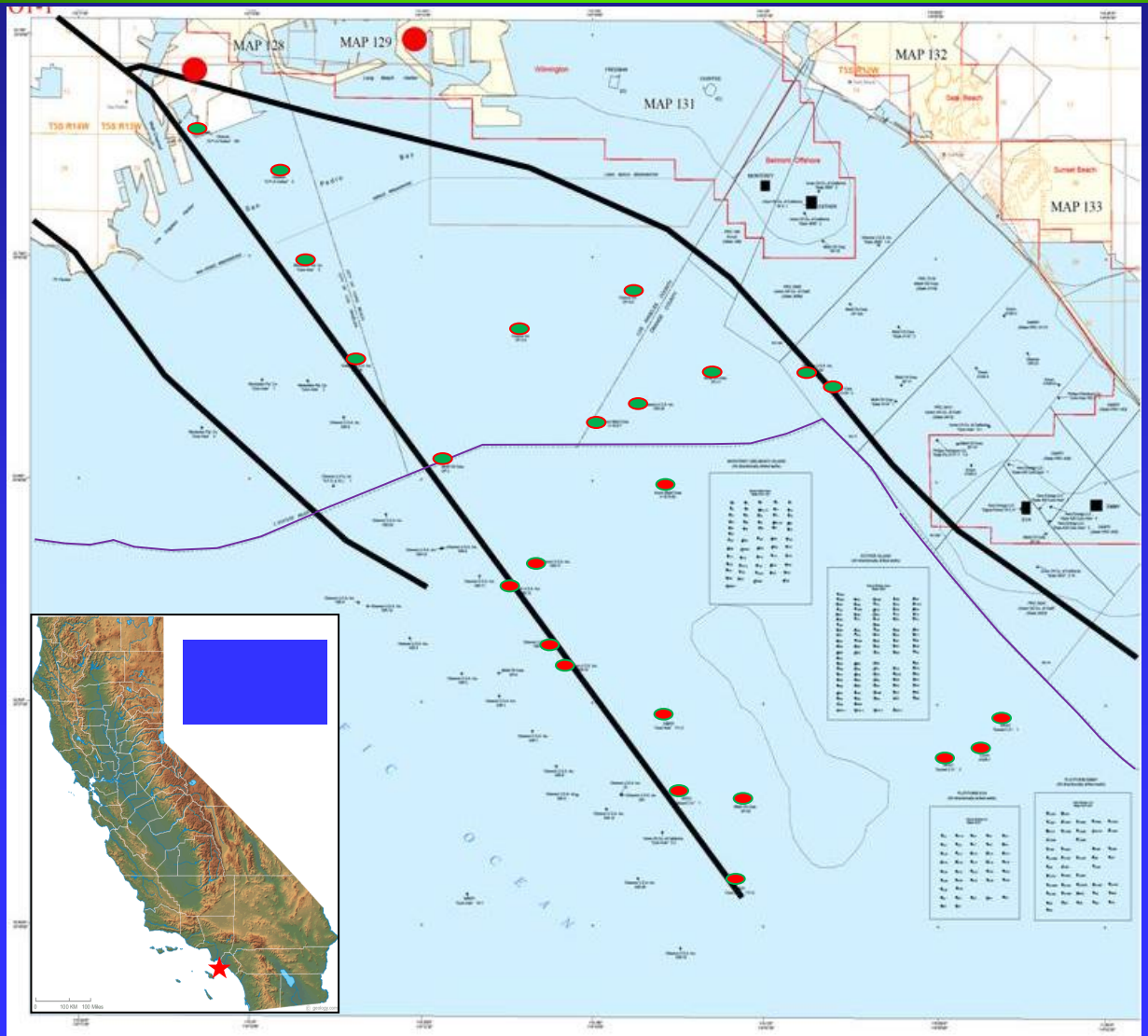

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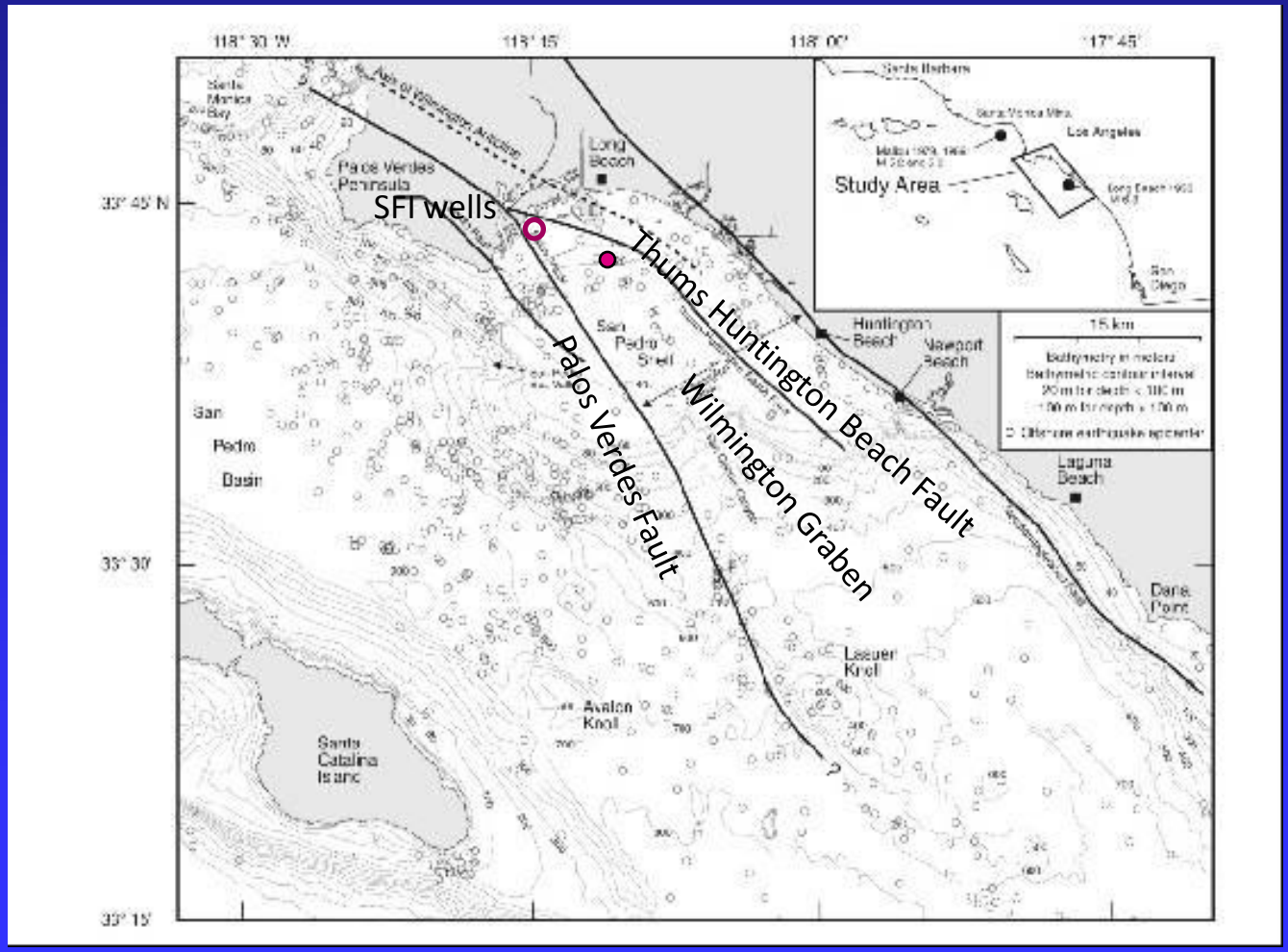
One well directionally drilled from City of Los Angeles property, in collaboration with the Terminal Island Renewable Energy Project (municipal sludge injection for enhanced treatment, CO2 sequestration, and methane generation). This will target shallower Pliocene.

One well will be directionally drilled from Port of Long Beach Property, in support of Green Port Program. This will target deeper Miocene.



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- **Provides site for additional characterization well into North Wilmington Graben**
- **18 months daily injection (300tons/day) of organic sludge for CO2 sequestration and waste to energy (w/ monitor well)**
- **Class V UIC permits; Extensive Public Outreach; 11 Neighborhood Council Votes; City Council Approval**
- **CEQA review, AQMD review, RWQCB review**
- **Continuous fiber optic temp monitoring, microseismic monitoring, web display of operations, pressures, rates**
- **Initial reservoir and geomechanical modeling to be leveraged and expanded to larger Graben Area**

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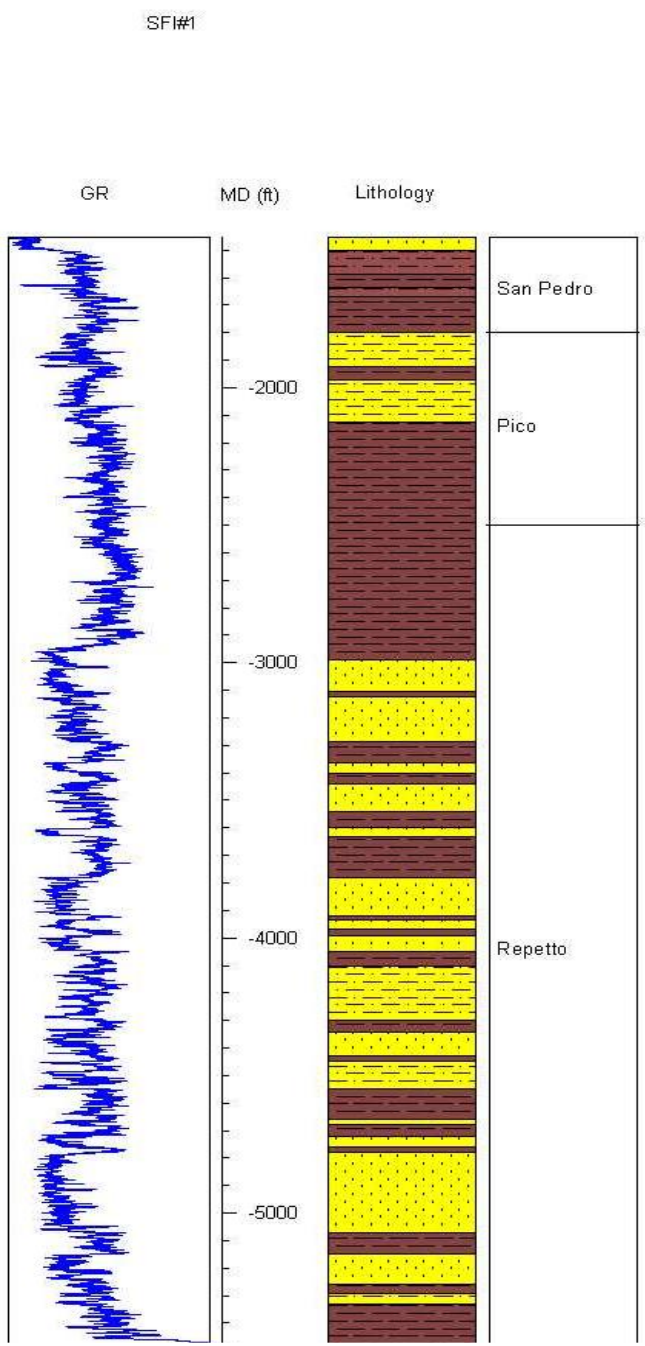

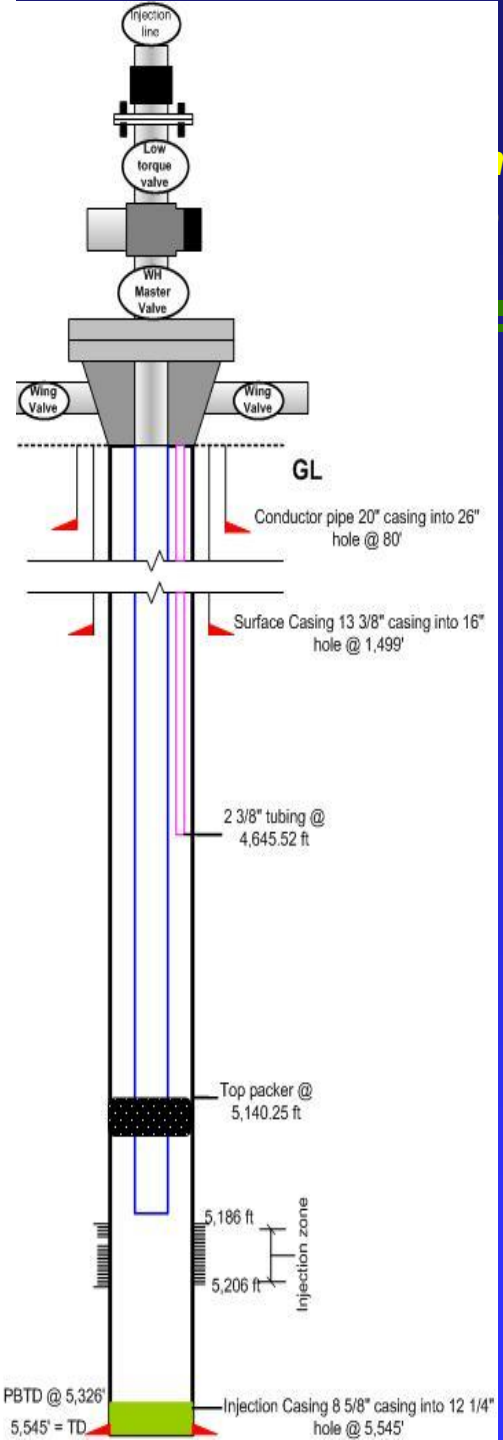

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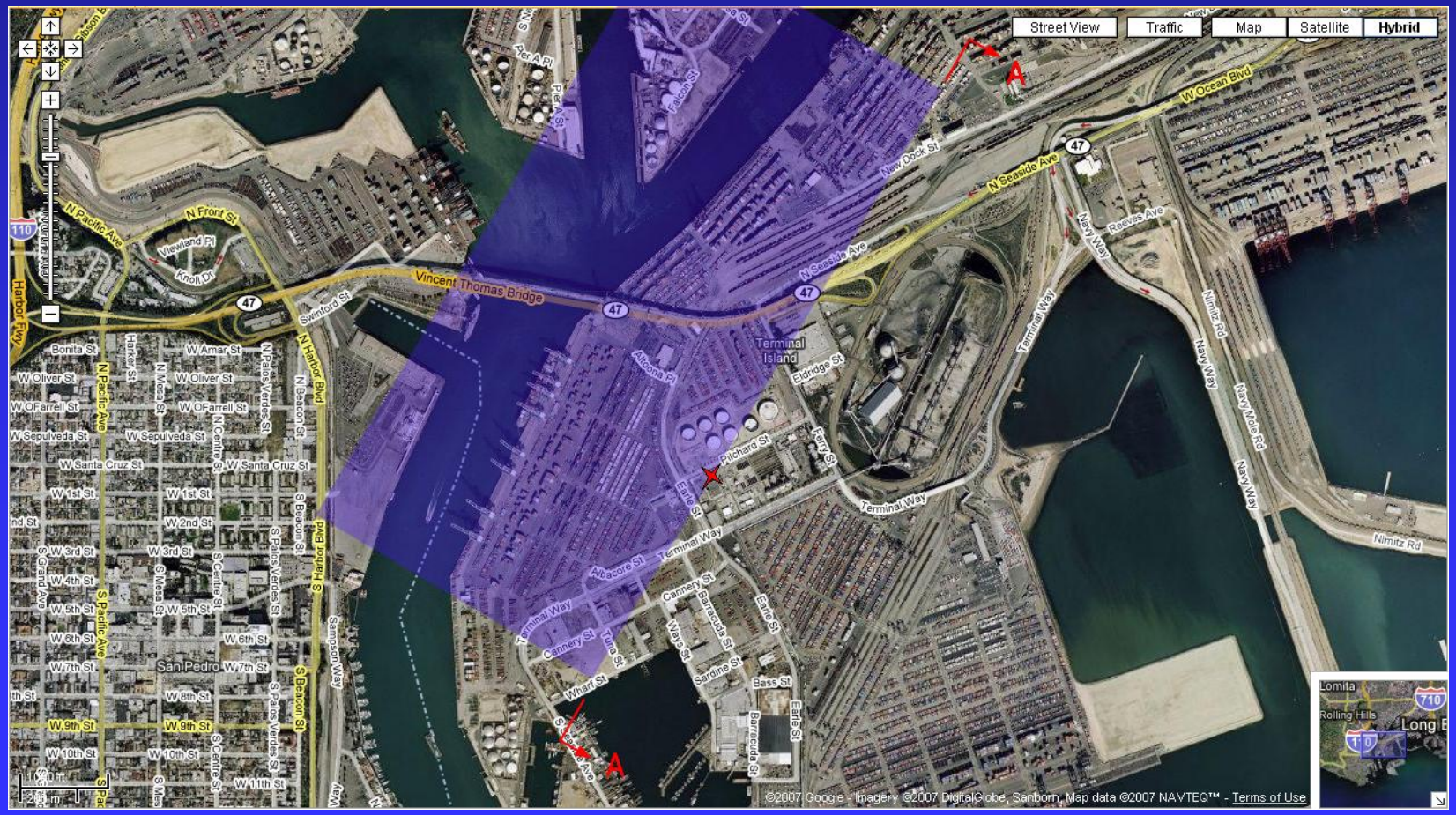
Model Area



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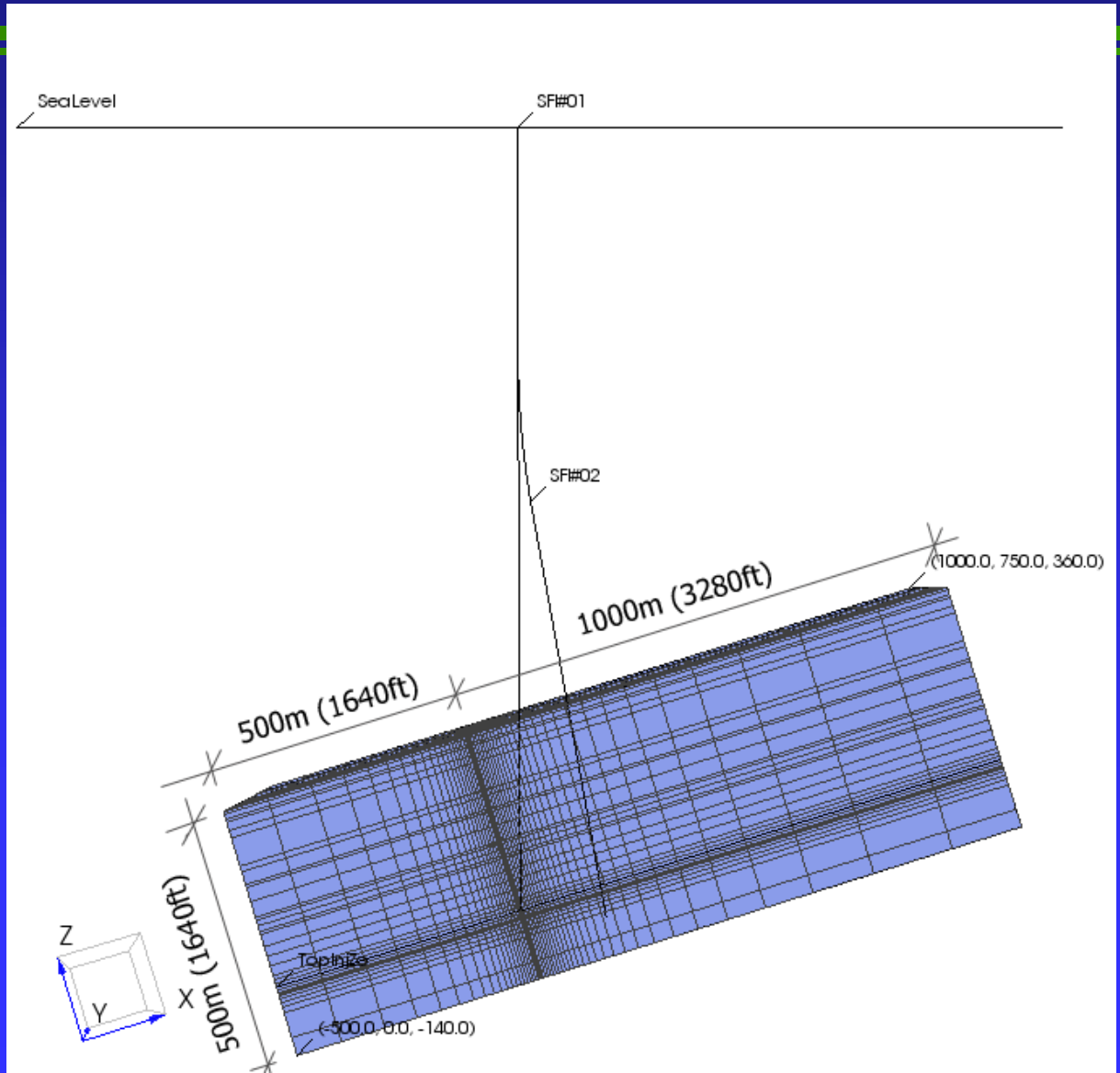

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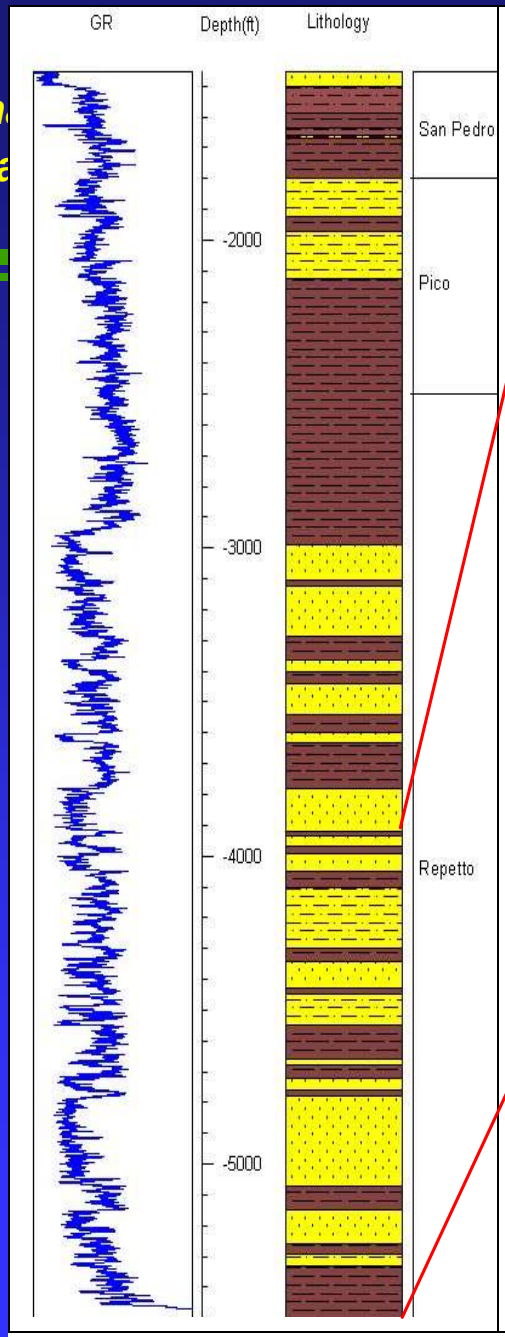
Ch... Wilmington
Gra... rage of CO2



Top from sea level [m]	Bottom from sea level [m]	Thickness [m]	
1183	1187	5	SHALE
1187	1198	11	SAND
1198	1204	6	SHALE
1204	1222	18	SAND
1222	1237	15	SHALE
1237	1241	3	SILT
1241	1270	30	SILT
1270	1298	28	SILT
1298	1311	12	SHALE
1311	1317	6	SAND
1317	1329	12	SAND
1329	1338	9	SAND
1338	1344	6	SHALE
1344	1375	30	SILT
1375	1390	15	SHALE
1390	1408	18	SHALE
1408	1414	6	SILT
1414	1426	12	SHALE
1426	1439	12	SAND
1439	1445	6	SHALE
1445	1533	88	SAND
1533	1558	24	SHALE
1558	1575	17	SAND
1575	1600	26	SHALE
1600	1612	12	SILT
1612	1666	53	SHALE

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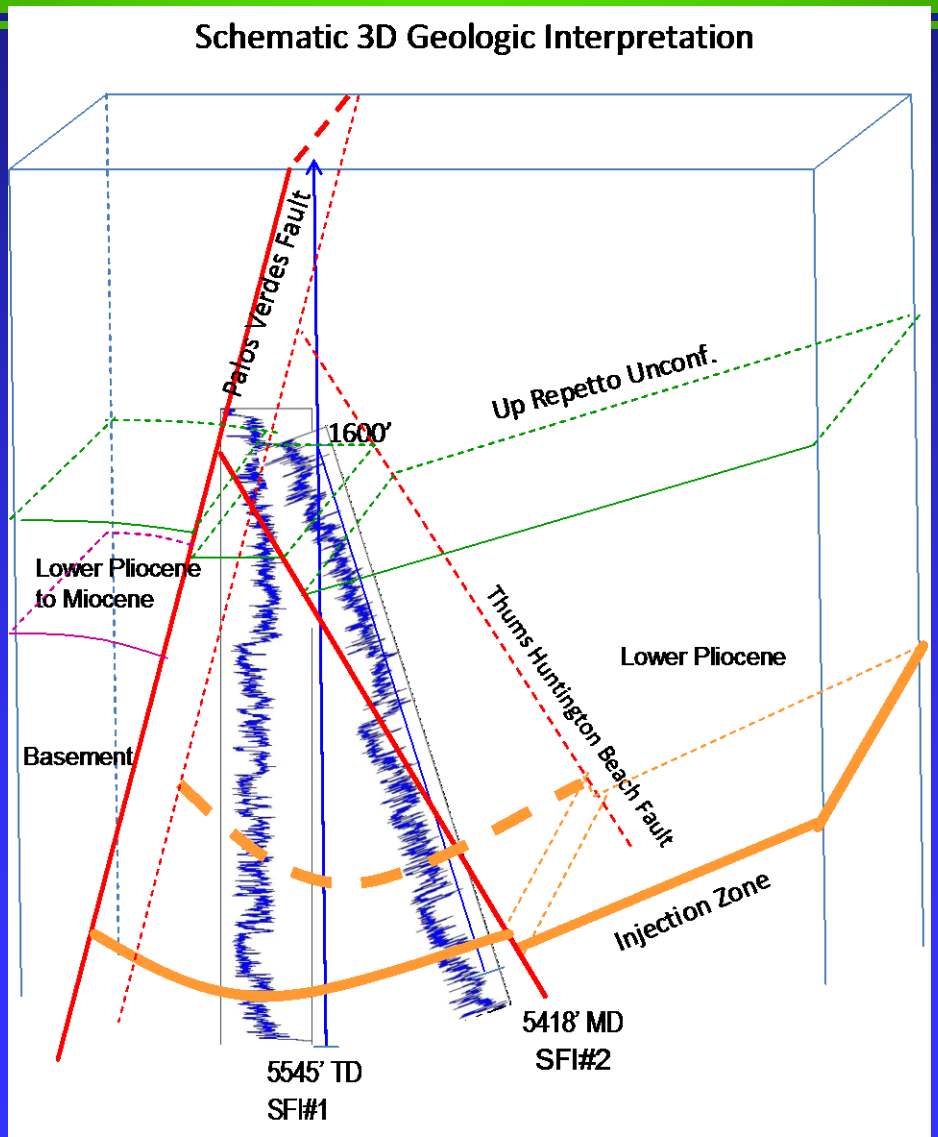

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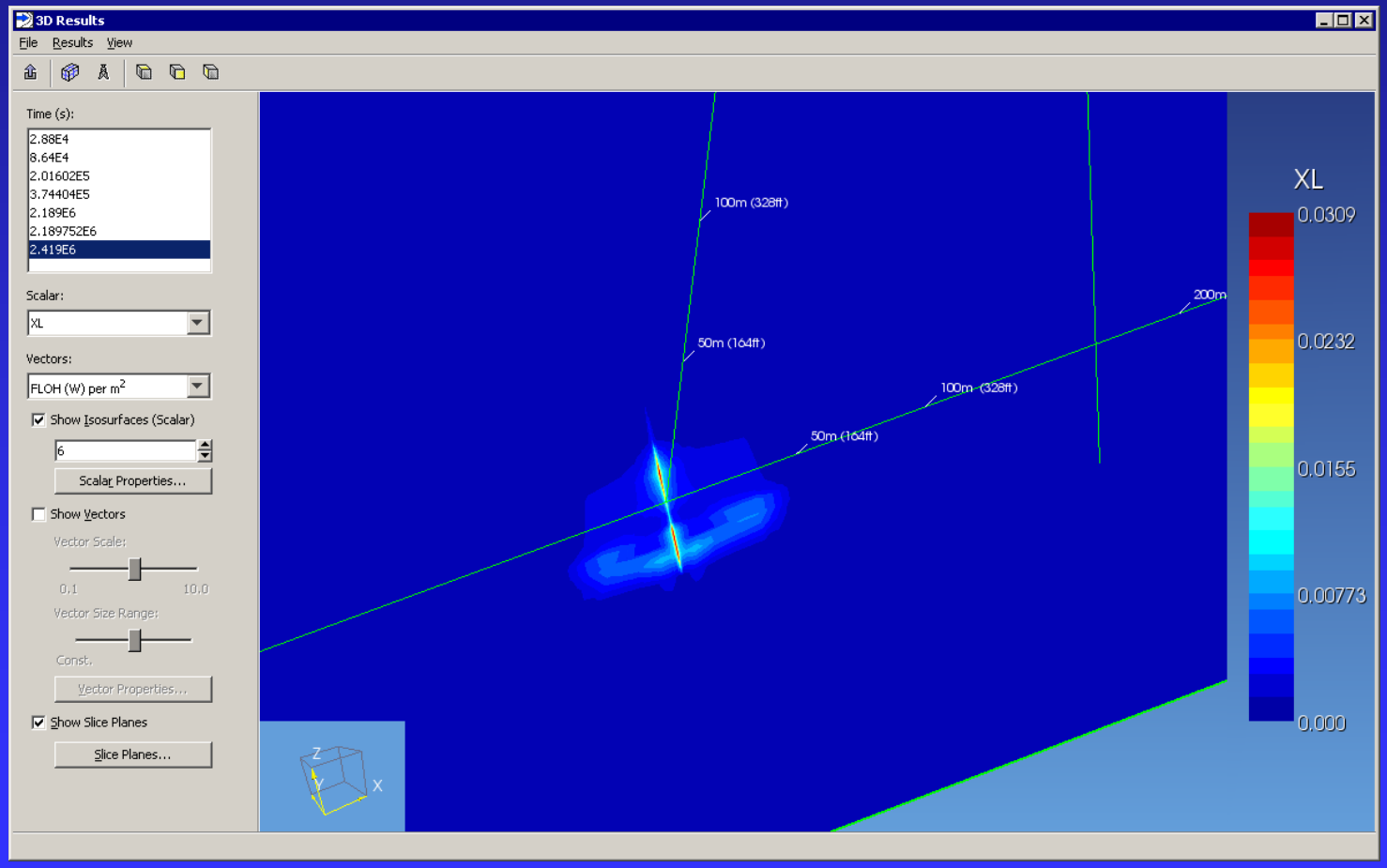

Figure 30: Mass fraction of CO2 in liquid phase after 28 days – symmetry plane

Summary and Next Steps:

1. **Characterization project includes:**
   - Seismic review and new acquisition
   - Well review and 3D geologic model development
   - New well drilling, coring, logging, and injection testing
   - CO2 migration simulation
   - Geomechanical modeling and risk assessment
2. **Initial well review underway for both State and Federal Waters**
3. **Well design and planning underway**
4. **Existing simulation models to be extended and repeated for additional areas**
5. **Key objective to quantify and verify about 75MM tons storage capacity**